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by

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16. ABSTRACT

The safe disposal of hazardous waste, the understanding of acid rain related effects, and the attainability of high water quality are but a few examples needing regional consideration for their management. A regional approach to environmental management is facilitated by identifying ecologically homogeneous land types within broad geographic regions. To address this need, the ecological characteristics of major land types in the eastern half of the conterminous United States are generated by a computer directly from the maps of the National Atlas. Thematic maps from the Atlas representing land surface form, surficial geology, soils, and potential natural vegetation were digitized and used in the computer for an overlay analysis. The joint spacial correlation of the like ecological characteristics were evaluated based on these maps and boundaries of major ecologically homogenous land types were drawn using computer graphics. The problems of digitization accuracy, editing, and the procedure for group of the orginal maps and tabulated areal extent of grouping within each map are presented for reference. The effort is continuing to analyze land types in the western United States. Examples of application of these maps are also given in the paper.

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The safe disposal of hazardous waste, the understanding of acid rain related effects, and the attainability of high water quality are but a few examples needing regional consideration for their management. A regional approach to environmental management is facilitated by identifying ecologically homogeneous land types within broad geographic regions. To address this need, the ecological characteristics of major land types in the eastern half of the conterminous United States are generated by a computer directly from the maps of the National Atlas. Thematic maps from the Atlas representing land surface form, surficial geology, soils, and potential natural vegetation were digitized and used in the computer for an overlay analysis. The joint spacial correlation of the like ecological characteristics were evaluated based on these maps and boundaries of major ecologically homogenous land types were drawn using computer graphics. The problems of digitization accuracy, editing, and the procedure for grouping of like characteristics are discussed. Summarization of the original maps and tabulated areal extent of grouping within each map are presented for reference. The effort is continuing to analyze land types in the western United States. Examples of application of these maps are also given in the paper.

INTRODUCTION

Map-overlay procedures have been used to accomplish diverse objectives. Some examples include urban planning (McHarg 1969), relating the ecology of aquatic to terrestrial systems (Omernik et al. 1981), determining environmental suitability for facility siting (Hepner 1981), and selecting research sites representative of agronomic conditions for crop production (Ford and Nielsen 1982). Map overlay procedures can be used as a tool in delineating boundaries of lands that most typify a region. Environmental data collected within these most typical lands offer a greater potential utility to understanding the region as whole. This procedure was used by Lomnitz (1983) to define sampling streams for use attainability, by Hughes (in press) for selecting control streams to assess impact of metal mining and by Shirazi (1984) to locate representative abandoned hazardous waste study sites.

Omernik and Powers (1983) used a similar regional approach to develop a synoptic overview of sensitivity of surface waters to acidification. The pressing problems of acid precipitation could make even greater use of this type of mapped information for the organization, collection and interpretation of data from acidified water bodies within geographic regions and, more locally, at specific sites (Omernik, personal communication).

This study was motivated by the above needs but mainly by the immediate and long range problems of managing hazardous waste on a regional level. Hazardous chemicals entering the terrestrial environment contact the soil; their interactions with soil is one of the most important considerations. Unfortunately, there are as many as 11,516 recognized soil series (USDA, SCS 1969), each with diverse physical and chemical characteristics, making case by case studies impractical. However, soil properties and the way they interact with chemicals are strongly influenced by regional topography, climate, potential vegetation, etc. Therefore, it would be desirable to exploit the regional pattern to reduce the number of variables involved in hazardous waste-soil interactions to a few dominant characteristics within a region.

Accordingly, a limited number of reference or "benchmark" soils with prespecified physical and chemical characteristics must be identified within a geographic region to facilitate the management of waste in that region as a whole, leaving more particular problems to be solved with local or site-specific data.

Vast quantities of existing physical and chemical soil data can be used to define and relate benchmark soils with geographic regions. This requirement necessitates the use of a computer for mapping and data analysis.

The study presented here is one of the steps leading to that objective. Subsequent efforts to organize the soil data will be consolidated with this study to accomplish the stated goal.

THE DATA BASE

The National Atlas of the United States (USDI, USGS 1970) contains a diverse regionalized data base representing major components of the ecosystem in a geographic region. The scale of the maps are 1:7,500,000, i.e., 1mm = 7.5 km, thus they bring out only those environmental characteristics that, on the average, hold true over a whole region. Details that do not pertain to generalized understanding of a large area are omitted. Selected maps from the Atlas are used in an overlay procedure to classify land units east of the Rockies representing regional characteristics.

Selection of maps in general must provide components of climate, geology, and biology. That is, components that are essential in understanding the composition and functioning of an ecosystem. But in particular, maps supported with the greatest data base and widespread use would be preferred. There is an element of arbitrariness regardless of selection made even if differences in final result might be minor. Furthermore, in this paper our aim is less toward making a precise selection of the components than it is to develop a methodology for use with any selection. Consequently, we follow an earlier approach (Shirazi 1984) and use the following four maps: the map of potential natural vegetation (Kuchler 1966, 1964), the soils map (USDA, SCS 1967), land surface map, (Hammond 1964), and the surficial geology map (Hunt 1979).

The four maps were digitized in segments corresponding to divisions of Bailey's Ecoregion Map (Bailey 1967). A transparent sheet of metric graph paper with 1 mm divisions was placed over a Bailey Division and manual digitization of the features of each map was performed, row by row. The information was then condensed by pairing coded map features appearing in each row with the column number of the cell in which the feature last occurs. In this manner, a string of repeated similar map units were represented only by one position number in a row and by the code of its map feature. All cells outside a division boundary were encoded as -1. The condensed data were stored in a computer and decoded when needed to reconstruct a computer map image suitable for line printer output or CALCOMP plotter.

In retrospect, we have continually underestimated the effort and dedication required for accurately digitizing the maps used in this study. First, the maps should have been digitized as a unit, overlayed by a single sheet of graph paper (or computer plotted geographic coordinate lines), to avoid the need for merging the parts together. Second, even though maps were eventually digitized manually, we began the work with machine digitization by tracing polygons and using an existing computer program to convert polygons into grid patterns of 1/32" resolutions. However, excessive error was detected when we overlayed the maps. For example, for the area corresponding to the southeastern United States (Bailey ecoregion 2300) the sum of the partial areas of a four-overlayed map accounted for only 88% of the area of each map. We were unable to detect the source of error and abandoned machine digitization in favor of a more time consuming but more tractable manual digitization. We do not necessarily advocate our approach, however. A comprehensive treatment of various options and available programs are given by Dangermond (1982). Resource limitations alone may force various users away from an otherwise optimal approach.

Both machine digitization and manual digitization are extremely taxing of human energy. The most obvious advantage of machine digitization is the direct entry of data into the computer, though this is not the major source of difficulty with manual digitization. The difficulty both methods share is the human fatigue encountered either in tracing the polygons with a tracer or counting grid cells manually. Errors do creep in but the challenge is detecting them during an editing process once the data are placed in the computer. Preplanned encoding of landmarks common among maps can help error detection by using the computer to compare maps at those landmarks. For example, boundaries of ecoregions, water bodies, state lines, geographic coordinates, etc., may be encoded during digitization of all maps so that by comparing these landmarks, one map is used to partially verify a second map. We have routinely used this aspect to edit our maps. Isolated errors found in this manner at times revealed several interrelated errors which were corrected.

A second step in the editing process was to search and list all codes of a map appearing in a digitized file and check them against an original list of codes, thereby detecting possible errors.

A third program checked the files row by row making certain the number of pairs and end-of-row codes were consistent. Since the maps were digitized in segments (four segments for the entire area east of the Rockies) by different individuals, the segments were appropriately aligned and merged with the neighboring segments to form a contiguous area. The alignment was necessary when neighboring segments were inadvertently rotated in relation to a fixed reference.

The final step in editing was accomplished by generating computer-drawn maps which were overlayed on equal-size original maps and searched for exact agreement of map codes. The detection and placement of irregularities was greatly facilitated by producing a much expanded line printer image of each map, pieced together and pasted on a wall.

COMPONENT MAPS

Rather than redraw the digitized maps in detail, which would merely reproduce the original data, it would be more useful for the purposes of this paper to highlight the spacial features of the land east of the Rocky Mountains by displaying major vegetation patterns, soil characteristics, land form features and modes of formation of the surficial material. Summaries of four maps used in our study are given in Figures 1 through 4. Tables 1 through 4 list the grouping features used in the summary maps. Whenever possible the higher levels or ranks of the original maps groupings were retained. The tables specify the number of original codes in each group.

The graphic display of map features in this study were done interpretively, retaining darkest shadings for map groups numbered 1 and progressively lighter shadings to higher group numbers. The groups themselves were arranged to reflect gradients of moisture and temperature; as much as possible groups numbered 1 reflect wet and warm conditions with higher numbered groups reflecting progressively drier and cooler conditions. In this manner, zonal characteristics are reflected for all components of the ecosystem roughly corresponding with different shades of gray. For example, the vegetation map groups retain darkest shading for wetlands of coastal and inland flood plains and the lightest shading for semiarid grasslands. The soil map groups are arranged so that group 1 represents the warm and wet soils and group 5 represents the warm and dry soils. The land form map groups are arranged so that group 1 is lowland flat plains and group 4 is mountains. The surficial geology map groups are arranged so that lower group numbers are retained for transported alluvial deposits and the higher number to colluviums.

This interpretive arrangement, though imprecise and somewhat artistic, replaces the need for publishing the maps in color while also providing an enjoyable understanding of the visual patterns.

We will attempt to retain the interpretive shading patterns in the integrated maps. In this manner, one can loosely relate the visual appearance of different shades of gray with biological activity in an area.

MAP INTEGRATION

The maps in Figures 1-4 are examples of biologic, geologic and climatic components of geographic regions in the United States east of the Rocky Mountains. A successful integration of these components will reveal ecologically homogeneous land types in the area. At the heart of the integration problem is the development of a rationale for grouping environmental characteristics from different maps in similar or "like" classes. While this is not an exact science, the outcome of an integration using a particular rationale does influence the utility of a map produced for environmental research and management purposes.

Environmental characteristics are spacially interrelated. The focus on one characteristic in an area points up information on several other related characteristics. For example, flood plain forests connote wet soils, alluvial deposits, and flat plains. Such a spacial interrelationship would be captured by grouping like objects and is represented in an integrated map by the appearance of large contiguous homogenous land types. These homogeneous land types define broad geographic regions, or eco-regions. Their boundaries however, might not be very distinct. Smaller transitional lands would separate larger regions. The transitional lands are influenced by and share characteristics of neighboring regions influencing them. This level of detail, while important at a local level must be minimized. It is important, therefore, that in grouping of "like" characteristics we begin with a small number of groups, carefully selected to reveal the unifying, rather than the diversifying features of an area.

In an earlier analysis of the southeastern United States, Shirazi (1984) used only two groups from each map, one that combined the characteristics of coastal and inland flood plains and second, the remaining characteristics from each map. This simple approach worked rather well. It enabled delineation of two distinct homogeneous land systems. One occupied the eastern and coastal flood plains (14%) and the other the Appalachian Highlands (14%) to the north of the region. The two land systems were connected with a large (40%) contiguous transitional system occupying the coastal piedmonts. Several smaller lands (4 to 9% each) of varying transitional characteristics linked one or more of major land systems together. The mosaic of the spacial patterns showed a continuous interaction and influencing of neighboring land characteristics. As much as 95% of the whole nine-state region could be explained with seven classes of land types.

The United States east of the Rockies is more heterogeneous than one of its parts, the southeast. The area is influenced by the marine environment from east and south, by the Rockies from west and by the Great Lakes and the Canadian land environments from the north. Much of the northern land masses are glaciated. The climate varies from north to south (mainly the temperature) and from east to west (mainly the moisture). Therefore, the extension of the approach must include added geographic features to achieve a greater resolution than would be possible by simply applying the method of the southeast to the whole region.

The mechanics of our approach can be translated into the requirement for regrouping items in Tables 1 through 4 to produce binary (or greater) number of classes. It is most convenient to regroup items in Tables 1, 3, and 4 corresponding, respectively, with vegetation, land form, and geology, in binary classes. Items closely associated with inland and coastal flood plains are classed as "like" and assigned class 1. Thus V1 (i.e., vegetation of class 1) includes item 1 from Table 1, while F1 contains item 1 of Table 3 and G1 contains items 1, 2, 3, 4 and 5 from Table 4. Soils, Table 2, would have three classes for obtaining a greater level of resolution. S1 includes items 1 and 2, S2 items 3 and 4, and S3 contains item 5. The total number of land types obtained with this approach is 2x3x2x2 = 24.

An even greater degree of resolution may be achieved by placing the glaciated land in a separate surficial geology class. However, correspondingly less definition is obtained as we increase the number of classes. This relationship is demonstrated by examining two additional alternatives, one with fewer number of land types than 24, and another with a greater number. The first alternative is based on binary classes in all map components (by combining moist and dry soils in S2). The total number of land types would be 2x2x2x2 = 16. The other alternative adds a new class to surficial geology just as mentioned above. The total number of land types would be 2x3x2x3 = 36. The three alternatives are compared in Table 5. It is evident that as the total number of land types increase from 16 to 36, the relative dominance of a few land type areas over others diminishes, making it difficult to discover a general trend. However, once a general trend is found, based on a more limited number of land types, a greater degree of resolution may be introduced when needed within a given land type by further subdivision of its components.

Although grouping appraoches may differ to meet various objectives, the examples given follow from the particular rationale we used to limit the number of possibilities. It is evident, therefore, that there exists a high degree of subjectivity in the grouping process which modifies the results of the map overlay procedure.

In this paper, we focus attention on the alternative with 24 land types by producing a map that delineates the spacial distribution of its dominant features in various shades of gray as shown in Figure 5. We have produced only 16 shades by combining 8 land types totaling less than 0.8% in areal extent with their immediate neighbors. The interpretive shadings discussed earlier in the paper are retained. The darkest shades in the map refer to inland and coastal flood plain ecosystems. The transition to other systems takes place as environmental characteristics of neighboring land types merge and influence each other. The shades of gray are intended to reproduce this interaction. For example, flood plains in predominantly moist soils have a lighter shade than in wet soils, and those with upland vegetation are lighter yet. Many examples can be visualized by comparing different shadings of the integrated map at a point in Figure 5 with some points in Figures 1-4.

SUMMARY AND CONCLUSION

We have used four maps from the National Atlas and generalized them first by regrouping the original data to show distinct thematic patterns. These are our Figures 1, 2, 3, and 4. We then discussed the need for further regrouping of items in each figure into even fewer classes for integrating the maps. For this second step we advocate the reliance on a rationale for classing "like" groups. We extended a rationale developed for the southeast to produce our integrated map in Figure 5. This map shows a mosaic of ecological features, highlighting various land types at a low level of resolution. A greater thematic resolution can be easily recovered in a reverse process by increasing the number of classes or groups, depending on the size of an area being examined and the need for detail in a given application.

The computerized map overlay procedure discussed in this paper can be helpful in discovering quantitative differences and similarities in geographic regions of the United States based on published data. It can be put to use to address specific objectives in environmental management and research benefitting from land classification. It is outside the scope of this paper to demonstrate these diverse applications. However, by comparing Figure 5 with Bailey's Ecoregion classification, one can find general correspondence with the major divisions and sections of Bailey. It is a relatively simple matter to change regrouping of characteristics to better match the two systems. More important than producing an agreement is the need for developing a rationale for a classification. This is a goal that the use of our approach can facilitate. It may well be necessary to use additional data bases or replace the ones we used with others. With regard to our main objective of hazardous waste site assessment, we

intend to pursue further analysis of land classes in the east as well as the western United States before we endeavor to take the next step of identifying benchmark soils.

Table 1. Potential natural vegetation of the United States east of the Rocky Mountains, regrouped from Kuchler (1966).

Vegetation Group	Name	Map Units (life forms)	% Area
1	Inland and Coastal Flood Plains	14	10
2	Broadleaf and Needleleaf Forests	5	30
3	Broadleaf Forests	6	25
4	Needleleaf Forests	3	3
5	Shrubs and Grasslands	9	14
6	Grasslands	12	18
		49	

Table 2. Zonal soils of United States east of the Rocky Mountains, regrouped from USDA SCS (1969).

Soil Group	Name	Map Units	% Area
1	Warm and Wet Soils	30	13
2	Cool and Wet Soils	1	0.6
3	Warm Moist Soils	89	56
4	Cool Moist Soils	25	12.4
5	Warm Dry Soils	33	18
		178	

Table 3. Land surface forms of the United States east of the Rocky Mountains, regrouped from Hammond (1964).

Land Form Group area	Name	Map Units	% Area
1	Plains (flat, smooth, irregular)	13	66
2	Tablelands (moderate to high relief)	8	5
3	Plains with hills and mountains	12	6
4	Open hills and mountains	20	17
5	Hills and Mountains	16	6
		69	

Table 4. Surficial geology of the United States east of the Rocky Mountains, regrouped from Hunt (1979).

Surficial Group	Name of Deposits	Map Units	% Area
1	Shore deposits	2	2
2	Wind deposits	4	12
3	Organic deposits	2	4
4	Lake and Stream deposits	4	15
5	Glacial deposits	5	26
6	Colluvium deposits	4	9
7	Sapprolitic deposits	15	32
		36	

Table 5. Combined land characteristics and areal extent of land types of the United States east of the Rocky Mountains. VSFG refers to potential natural vegetation, soils, landform and surficial geology respectively. Class 1 of each refers to wet or flood plain conditions.

16 Land Types		24 Land Types		36 Land Types	
USFG	% Area	VSFG	% Area	VSFG	% Area
2211	28.7	2211	23.8	2223	14.7
2212	19.8	2222	14.9	2212	14.1
2222	17.7	2212	13.0	2213	13.2
2221	14.8	2221	12.5	2211	9.9
2111	6.0	2312	6.6	2222	8.5
1111	4.3	2111	6.2	2313	6.6
1211	3.1	2311	4.8	2111	4.7
2112	1.8	1111	4.3	2221	4.1
1221	.75	2322	3.0	2311	3.9
1212	.73	1211	2.5	2323	3.05
2121	.31	2321	2.3	2321	2.3
1112	.29	2112	1.7	1211	2.0
		1221	0.69	2113	1.8
		1212	0.58	2112	1.3
		1311	0.48	2312	.81
		2121	0.34	1222	.56
		1112	0.34	1311	.53
		1312	0.19	1213	.51
		1222	0.09	1212	.48
		1321	0.04		
		2122	0.04		
		1121	0.02		
		1122	0.01		
		1322	0.00		

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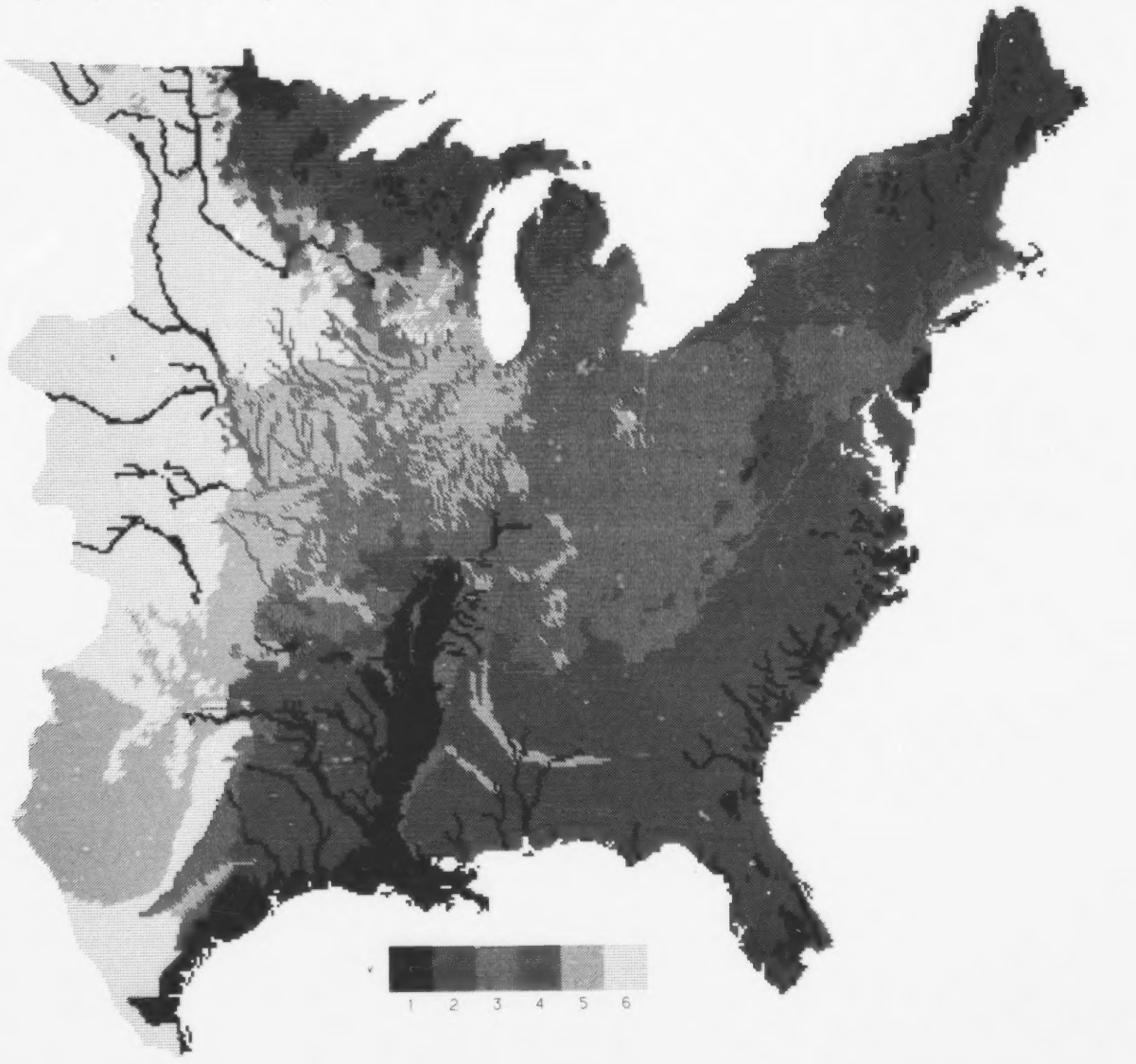

Fig. 1. Potential natural vegetation. See Table 1.

Fig. 2. Zonal soils. See Table 2.

Fig. 3. Land surface forms. See Table 3.

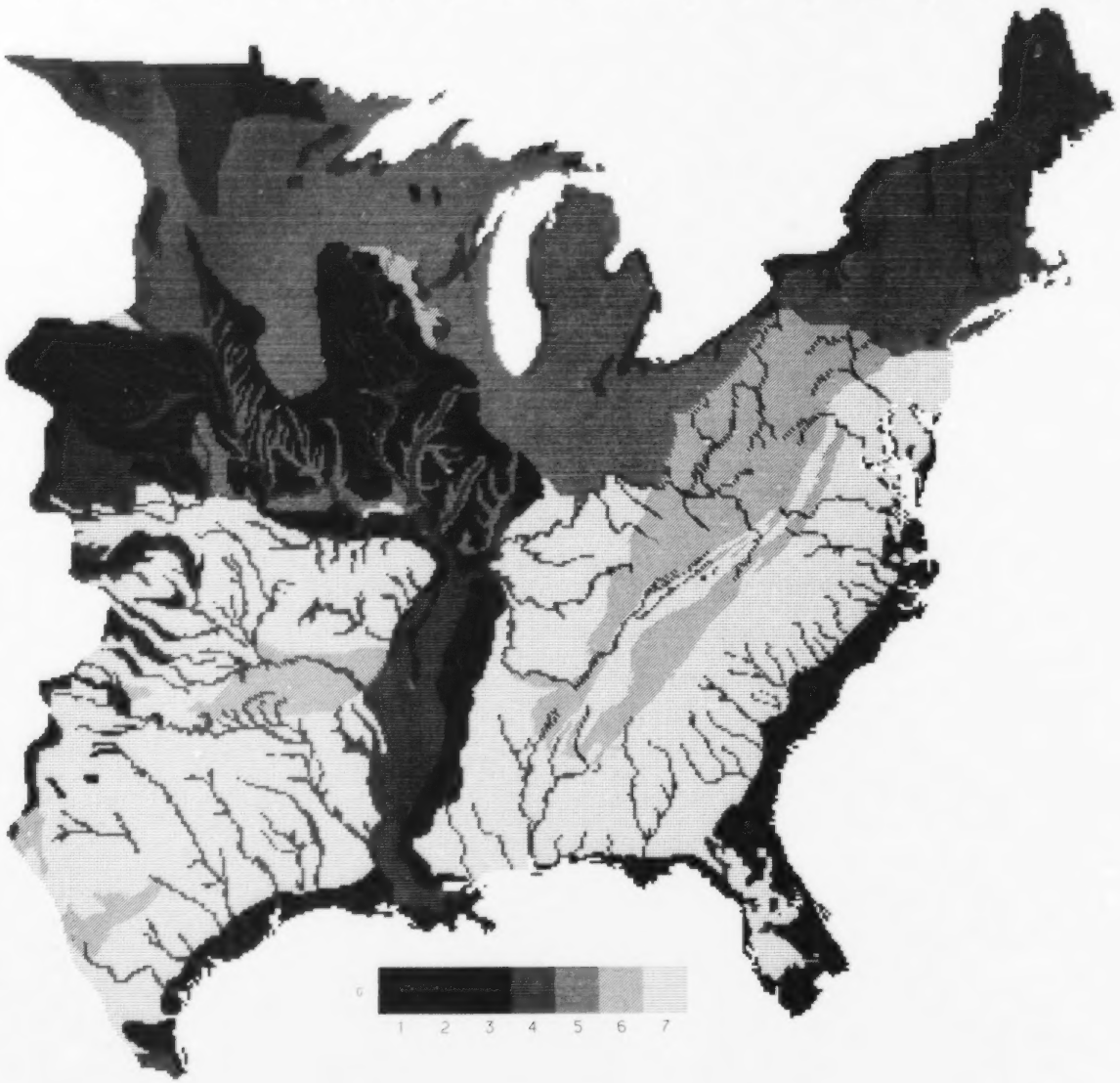

Fig. 4. Surficial geology. See Table 4.

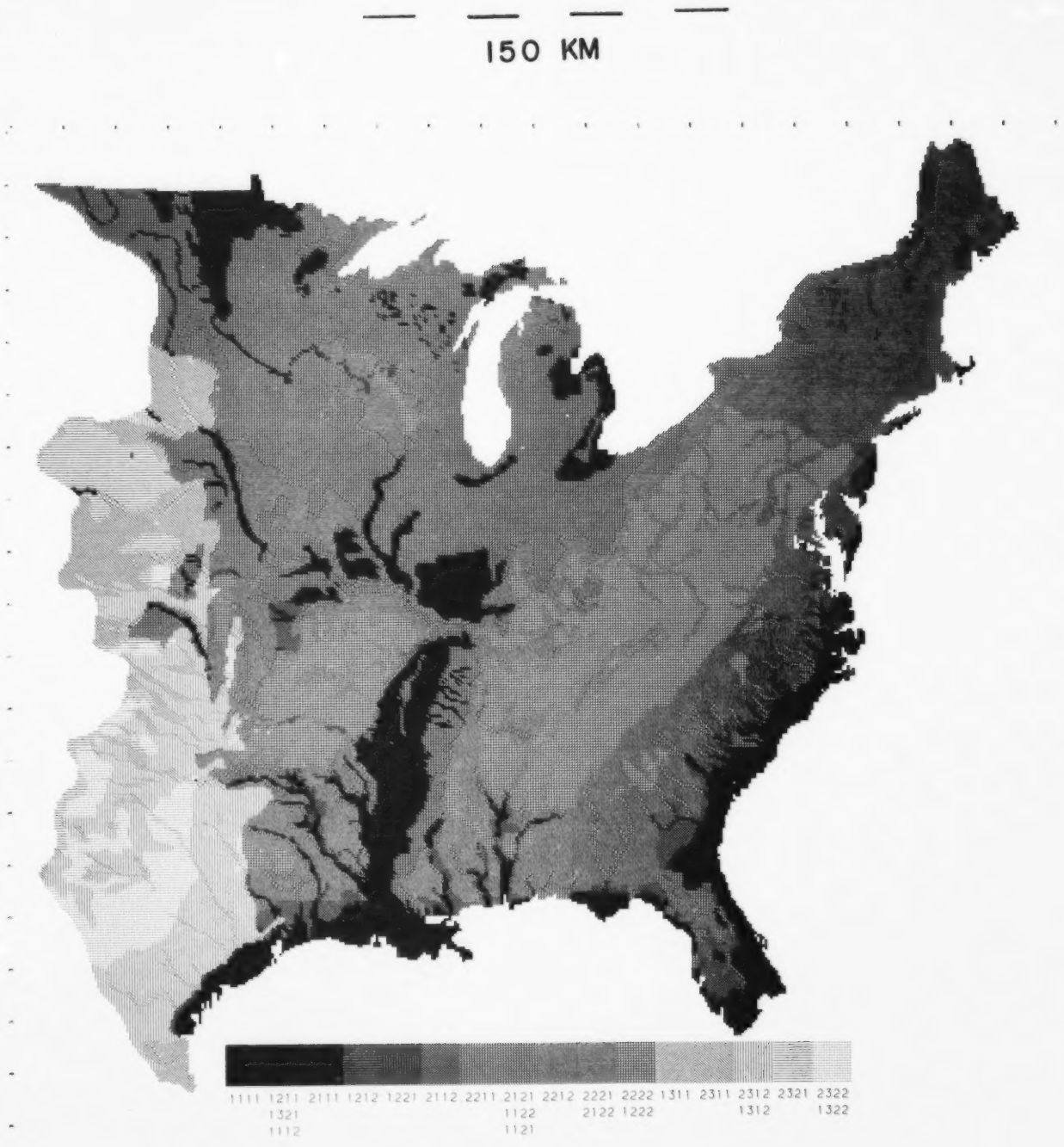

Fig. 5. Homogeneous land types. See Table 5, middle column.